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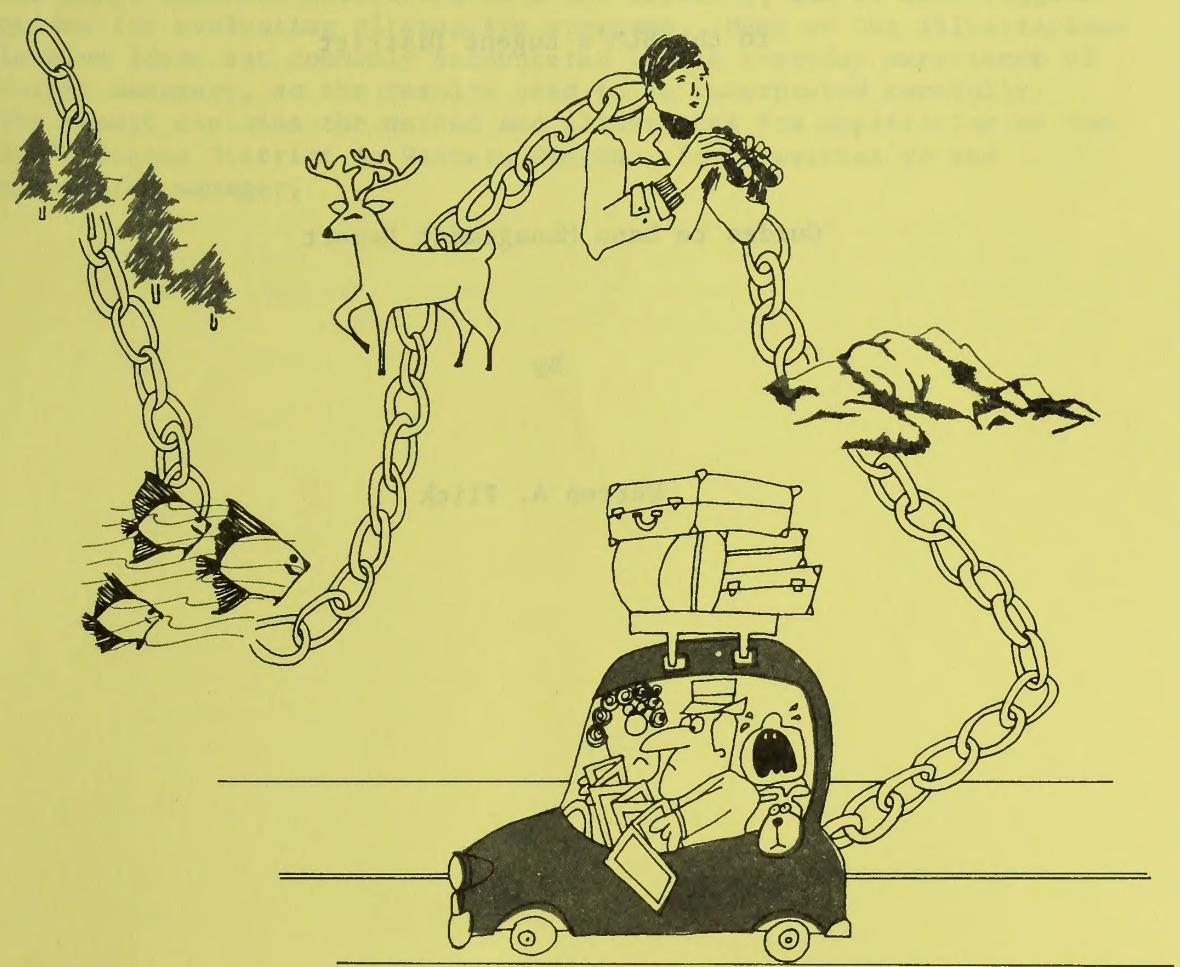
U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

RESOURCE FLOWS AND VALUES



by Warren A. Flick

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RESOURCE FLOWS AND VALUES

in the BLM's Eugene District

Guides to Land Management Report

By

Warren A. Flick

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Foreword

The research reported here is part of the Guides to Land Management Project which was initiated by the Bureau of Land Management in 1965. The purpose of the Project is to provide resource managers with techniques for identifying alternative measures and their consequences. The work is addressed to the problems of decision making in a complex natural-resource system.

This report presents a technique that helps managers understand the scope of their work. The method deals simultaneously with all the major resource activities on a BLM district, and it also suggests guides for evaluating alternative programs. Many of the illustrations involve ideas not commonly encountered in the everyday experience of forest managers, so the results need to be interpreted carefully. The report explains the method and illustrates its application on the BLM's Eugene District in Western Oregon. It is written to the practicing manager.

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The Problem

The problem addressed here is the problem of multiple use, of describing and selecting alternatives. The problem is common in forest management and it is also difficult. Foresters must make decisions about many resources, and each decision about a particular resource has impacts on many of the other forest outputs. And the decisions that each forestry firm makes must satisfy the demands of the firm's sponsors. In the case of public agencies like the Bureau of Land Management, demands from Congress, private groups, and other public agencies must all be considered in the process of management. New priorities are written into legislation, new budgets emphasize different programs, and new interpretations are given to existing policies. Forestry agencies influence such changes and, inevitably, respond to them. The agency's task is to incorporate such changes into its program in a way that best meets the demands of the publics it serves.

In the Douglas-fir region of western Oregon, multiple-use problems are especially acute because of the regions valuable resource endowments. In western Oregon, much of the BLM's land is within easy access of Oregon's largest cities, and it is used intensively by local campers, hunters and fishermen. And tourists come by the thousands to see the state's unique natural heritage. The forests of western Oregon provide the nation with billions of board feet of sawtimber and other wood products, and the major rivers yield abundant supplies of water.

Development of any of these resources influences prospects for the others. BLM administrators are aware of such interrelationships, and they are forced to deal with them in their daily work. Their task is necessarily interdisciplinary and integrative, yet they have few analytical tools to help them describe and select alternatives in an integrated way.

This report describes a method of analyzing multiple-use systems. The principal result is a table of numbers that shows the quantitative effects activities have on one another, but procedures for using this information in the context of multiple-use decision making are also discussed. The results are useful to resource managers generally, who will look for opportunities to apply the method to their situations, and to BLM foresters who will gain new insights into their daily work.

Input-Output Analysis

The procedures used here to analyze a multiple-use system are those of input-output analysis. Input-output models are generally used to study regional or national economies, and the properties of the model are usually described in the context of economics. When used to study a forestry system, the model retains its basic properties, but its components are much different. This section discusses the model in an economic context.

The General Scheme

The model is called 'input-output' because it emphasizes production as characterized in Figure 1. Consumer demand is the force that pulls an economy into productive activity. The significance of demand arises from the fact that consumer well-being is an important goal of economic activity, and input-output models draw attention to this goal. Demand generates production, and production requires inputs. Industries buy inputs from other industries, and they hire labor. In most input-output models, labor is the primary input, a somewhat special input, because it is not produced by any of the industries. The inputs that industries buy from one another are called intermediate inputs.

These simple ideas about production are put to work in input-output models with the aid of a large table, called a flow table, which shows the transactions, or product flows, among industries. Figure 2 is a diagram of such a table. The industries of the economy are listed along the top and left margins. The last column and row are reserved for final demand and primary input.

Inputs to each industry are shown in a column. Each industry uses primary input, and this is represented by the arrow at the bottom of the column. The other arrows in the columns represent intermediate inputs from other industries. The output of each industry is recorded in a row. The horizontal part of each arrow indicates the source of a particular flow, and the vertical part indicates the destination. Each bent arrow, then, represents both an output and an input. For example, the arrow in the circle indicates that steel is used to produce coal. The horizontal arrows to final demand indicate the products that leave the production network and go to households.

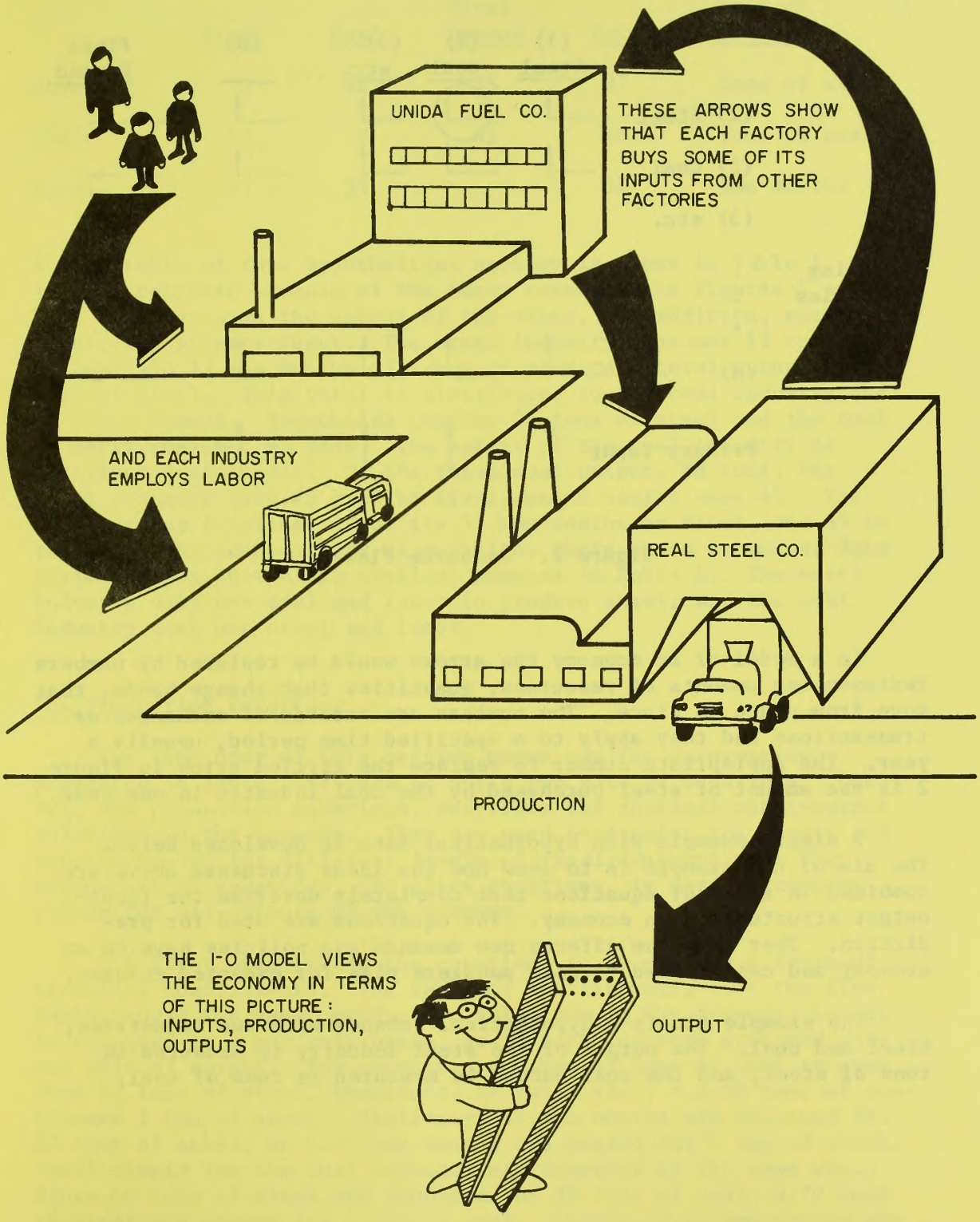

UNIDA FUEL CO.
THESE ARROWS SHOW THAT EACH FACTORY BUYS SOME OF ITS INPUTS FROM OTHER FACTORIES
AND EACH INDUSTRY EMPLOYS LABOR
REAL STEEL CO.
PRODUCTION
THE I-O MODEL VIEWS THE ECONOMY IN TERMS OF THIS PICTURE: INPUTS, PRODUCTION, OUTPUTS
OUTPUT

FIG. I THE ECONOMY

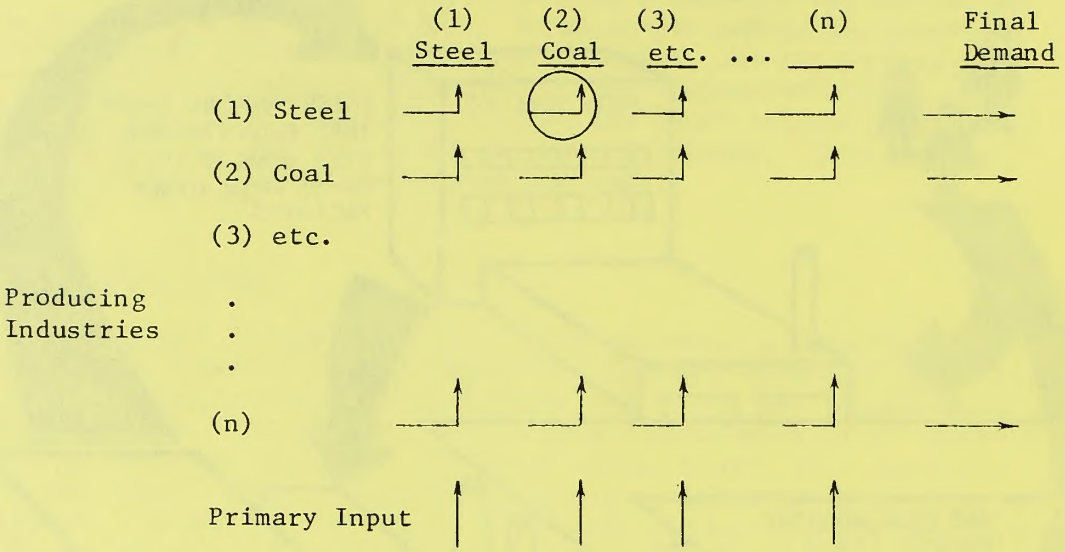


Figure 2. Resource Flows

In a model of an economy the arrows would be replaced by numbers representing amounts of resources, quantities that change hands, that move from place to place. The numbers are records of exchanges or transactions and they apply to a specified time period, usually a year. The appropriate number to replace the circled arrow in Figure 2 is the amount of steel purchased by the coal industry in one year.

A simple example with hypothetical data is developed below. The aim of the example is to show how the ideas discussed above are combined in a set of equations that completely describe the input-output structure of an economy. The equations are used for prediction. They show the effects new demands and policies have on an economy and can be used to help managers plan for expected changes.

The example treats a hypothetical economy with two industries, steel and coal. The output of the steel industry is measured in tons of steel, and the coal output is measured in tons of coal.

Table 1. Hypothetical Flow Data

	Steel	Coal	Final Demand	Total	Unit of Measure
Steel	0	62	25	87	tons of steel
Coal	43	0	45	88	tons of coal
Labor	17	35		52	man months

A flow table of this hypothetical economy is shown in Table 1. It is a concrete example of the ideas presented in Figures 1 and 2. Each industry uses the output of the other. In addition, each uses labor, the primary input. The steel industry consumes 43 tons of coal and 17 man months of labor to produce a total output of 87 tons of steel. This total is distributed to the coal industry and to final demand. Households consume 25 tons of steel and the coal industry consumes 62 tons. The output of the coal industry is distributed similarly. Of the total coal output, 88 tons, the steel industry uses 43 and the final demand sector uses 45. The labor sector furnishes 17 of its 52 man months to steel, and 35 to coal. In any economy, say of a region, there would be annual data corresponding to the hypothetical numbers in Table 1. The steel industry does use coal and labor to produce steel, and the coal industry does use steel and labor.

The Production Equations

The remainder of this section shows how the information presented in Table 1 is used to build two sets of equations. One set, the production equations, describes the physical input-output relations in the economy. They are used to predict the inputs and outputs needed for different levels of final consumption. The second set of equations, the price equations, is used to compute prices for all outputs of the economy.

The first step toward the equations is to compute a table of technical coefficients. The table of coefficients, like the flow table, shows the basic production relations in the economy, but it is computed on a per unit basis, as if each industry produced only one unit of output. For example, it takes 43 tons of coal to produce 87 tons of steel, therefore, it takes 43/87 = 0.50 tons of coal to make 1 ton of steel. Similarly, 17 man months are required for 87 tons of steel, so 0.20 man months are needed for 1 ton of steel. Coefficients for the coal industry are computed in the same way. Since 62 tons of steel are required for 88 tons of coal, 0.70 tons of steel are needed for 1 ton of coal. Lastly, 0.40 man months are required for each ton of coal. All these coefficients, shown in

table 2, describe the input proportions needed to produce one unit of each output. Since the final demand sector represents household consumption, not production, it has no associated technical coefficients.

Table 2. Technical Coefficients

	Steel	Coal
Steel	0	0.70
Coal	0.50	0
Labor	0.20	0.40

The useful feature of the coefficients is they provide an alternate way of writing the flows shown in Table 1. For example, 'steel uses 43 tons of coal' can be written as, 'steel uses 0.50(87) tons of coal.' The total outputs of each industry can also be written in two ways, and these expressions of total outputs constitute the equations mentioned above. The equations are formed by writing each total output as a sum of individual flows. The total outputs are:

steel: $0 + 62 + 25 = 87$

coal: $43 + 0 + 45 = 88$

or, in terms of the technical coefficients:

$$\begin{aligned} &\text{steel: } 0\,(87) + 0.70(88) + 25 = 87 \\ &\text{coal: } 0.50(87) + 0(88) + 45 = 88 \end{aligned} \qquad (1)$$

Equation system (1) is the basic set of production equations, but it is specific to the data of Table 1. Before it can be used for predictions it must be generalized.

The aim is to predict the total outputs associated with varying levels of final demand. This can be accomplished if the technical coefficients are treated as constants, and final demands and total outputs as variables. Each coefficient is assumed to describe a general input requirement. If 0.70 tons of steel are needed for each ton of coal when 88 tons of coal are produced, then the same coefficient applies when more or less coal is produced. If the input proportions are fixed the total outputs will vary with final demands. Let Y_1 and Y_2 be the final demands for steel and coal respectively, and let X_1 and X_2 be the total outputs of steel and coal. Combining these letters with the coefficient gives,

$$\text{steel: } 0(X_1) + 0.70\ (X_2) + Y_1 = X_1$$
$$\text{coal: } 0.50(X_1) + 0\ (X_2) + Y_2 = X_2 \qquad (2)$$

Equation (2) is a system of two simultaneous equations, and it can be solved to express total outputs as functions of final demand. The solution can be obtained by several methods, and it is:[1]

$$X_1 = 1.5385\ Y_1 + 1.0770\ Y_2$$
$$X_2 = 0.7692\ Y_1 + 1.5385\ Y_2 \qquad (3)$$

The coefficients in Equation (3) bear a special significance, and they have a special name - interdependency coefficients. Their name is derived from the fact that they demonstrate the dependence among all industries. If Y_1 is increased by one unit, the first coefficient in each equation shows the impact of that increase on the respective total outputs. The second coefficient in each equation shows the impact of a change in Y_2.

The technical coefficients and interdependency coefficients are linked to one another in a useful way which is illustrated in Figure 3. The technical coefficients show the inputs needed for each unit of total output, and the interdependency coefficients show the total outputs needed for each unit of final demand. Taken together, the coefficients show both the outputs and inputs needed to support any given level of final consumption.

---

[1] One method is the method of substitution, demonstrated below. Substitute the steel equation into the coal equation to get,

$$X_2 = 0.50\ (0.70\ X_2 + Y_1) + Y_2$$
$$X_2 = 0.35\ X_2 + 0.50\ Y_1 + Y_2$$
$$0.65\ X_2 = 0.50\ Y_1 + Y_2$$
$$X_2 = 0.7692\ Y_1 + 1.5385\ Y_2$$

Resubstituting this equation into the original steel equation gives,

$$X_1 = 0.70\ (0.7692\ Y_1 + 1.5385\ Y_2) + Y_1$$
$$X_1 = 0.5385\ Y_1 + 1.0770\ Y_2 + Y_1$$
$$X_1 = 1.5385\ Y_1 + 1.0770\ Y_2$$

which completes the solution. This solution can be easily checked. If we substitute the original final demands into the equations we should get the original total outputs when solved. Substituting 25 and 45 for Y_1 and Y_2 in equation (3) gives,

$$X_1 = 1.5385\ (25) + 1.0770\ (45) = 87$$
$$X_2 = 0.7692\ (25) + 1.5385\ (45) = 88.$$

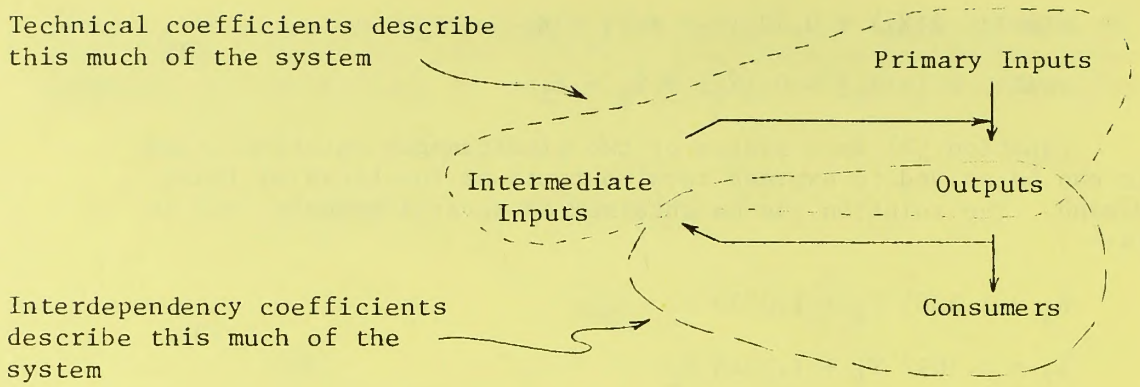
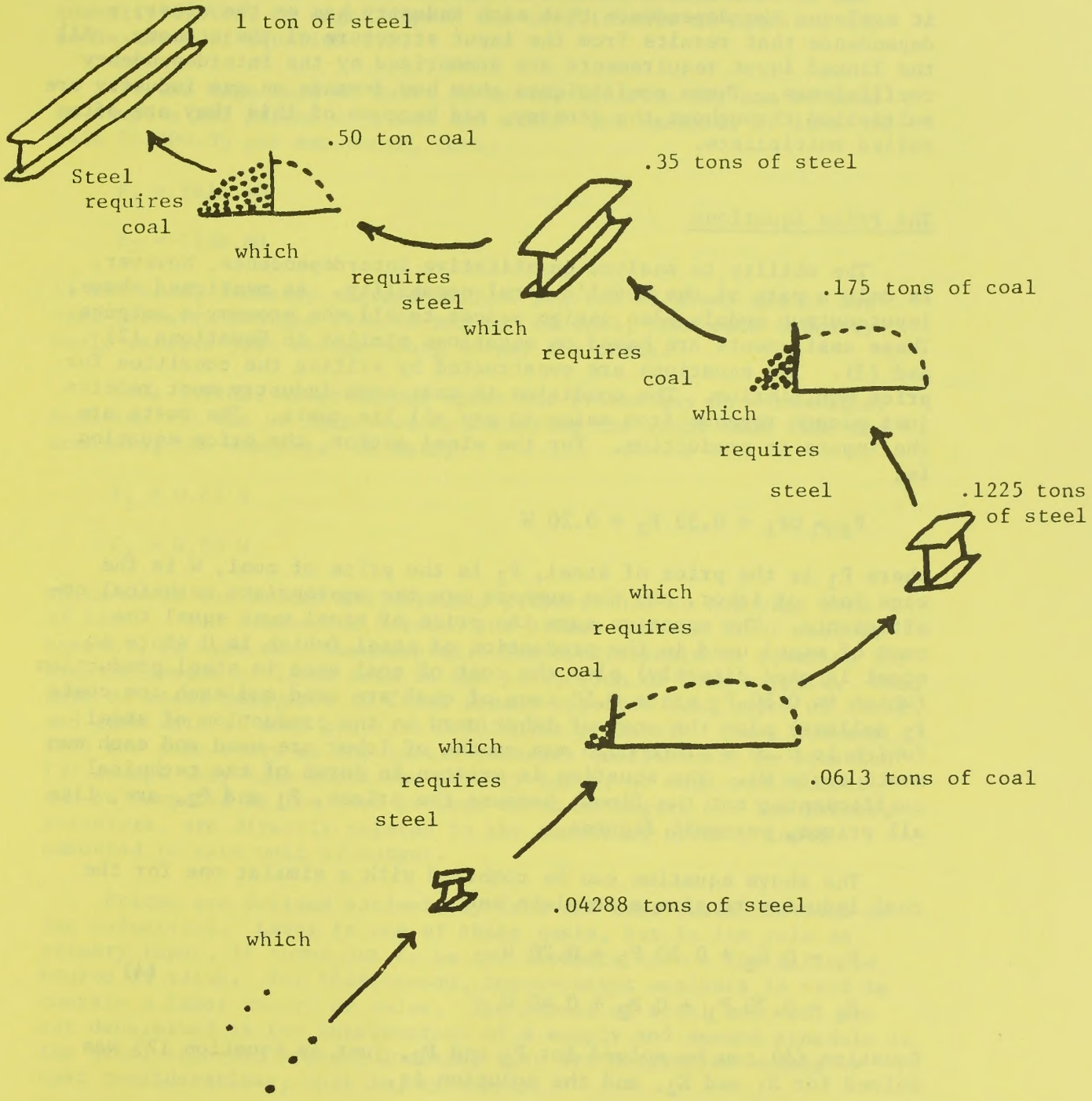


Figure 3. The Production System

The relationship between these sets of coefficients is based on the fact that each industry requires the output of the other. The production of one ton of steel for household consumption requires coal, and to make that coal, additional steel is needed. Therefore, the total output of steel must be more than what is needed for final demand. Figure 4 shows how the technical coefficients can be used to derive the interdependency coefficients, and the derivation involves these linked input requirements. The series tells why 1.5385 tons of steel must be produced to allow 1.0 ton for final demand. The picture describes what is needed to meet a final demand of one ton of steel. Another picture could also be drawn for coal.

The derivation involves the interdependence between steel and coal. The technical coefficients of Table 2 say that one half ton of coal is required to produce a ton of steel. The second column of Table 2 tells the amount of steel needed for one ton of coal (.70), so the one half ton of coal needed to produce a ton of steel requires, in turn, 0.35 tons of steel (0.70 x 0.50 = 0.35). The question can then be asked, how much coal and steel are needed for that 0.35 tons of steel? The next two steps in Figure 4 give the answer: if half a ton of coal is required for one ton of steel then 0.175 tons of coal are needed for 0.35 tons of steel. And if 0.70 tons of steel are needed for each ton of coal, then 0.1225 tons of steel are required for 0.175 tons of coal. This chain can be continued indefinitely, and each link involves smaller amounts of resources. The sum of all the steel used in this process is 1.5385 tons which is the first independency coefficient in the first column of Equation (3). The sum of all the coal used is 0.7692 which is the second interdependency coefficient in the first column of Equation (3). These calculations demonstrate that to produce steel for final demand, both industries must operate and their total outputs can be computed from the interdependency coefficients.



If continued, the total of all the units of steel would be 1.5385.
The total of all the units of coal would be 0.7692.

Figure 4. Linked Input Requirements

The above explanation is crucial in input-output analysis because it explains the dependence that each industry has on the other, a dependence that results from the input structure of the economy. All the linked input requirements are summarized by the interdependency coefficients. These coefficients show how demands on one industry are multiplied throughout the economy, and because of this they are often called multipliers.

The Price Equations

The ability to analyze quantitative interdependence, however, is only a part of the model's total capability. As mentioned above, input-output models also assign prices to all the economy's outputs. These assignments are based on equations similar to Equations (2) and (3). The equations are constructed by writing the condition for price equilibrium. The condition is that each industry must receive just enough revenue from sales to pay all its costs. The costs are the inputs to production. For the steel sector, the price equation is,

$$P_1 = 0P_1 + 0.50\ P_2 + 0.20\ W$$

where P_1 is the price of steel, P_2 is the price of coal, W is the wage rate of labor, and the numbers are the appropriate technical coefficients. The equation says the price of steel must equal the cost of steel used in the production of steel (which is 0 since no steel is used directly) plus the cost of coal used in steel production (which is 0.50 P_2 since 0.50 tons of coal are used and each ton costs P_2 dollars) plus the cost of labor used in the production of steel (which is 0.20 W since 0.20 man months of labor are used and each man month costs W). The equation is written in terms of the technical coefficients, not the flows, because the prices, P_1 and P_2, are, like all prices, per-unit figures.

The above equation can be combined with a similar one for the coal industry to give a complete set:

$$\begin{aligned} P_1 &= 0\ P_1 + 0.50\ P_2 + 0.20\ W \\ P_2 &= 0.70\ P_1 + 0\ P_2 + 0.40\ W \end{aligned} \qquad (4)$$

Equation (4) can be solved for P_1 and P_2, just as Equation (2) was solved for X_1 and X_2, and the solution is,

$$\begin{aligned} P_1 &= 1.5385\ (0.20\ W) + 0.7692\ (0.40\ W) \\ P_2 &= 1.0770\ (0.20\ W) + 1.5385\ (0.40\ W) \end{aligned} \qquad (5)$$

The structure of Equation (5) is very similar to that of Equation (3), and this fact may not be too surprising. Since the value

relationships employ the same technical coefficients used in the quantity system, we might expect the coefficients of Equation (5) to be those of Equation (3).

If the wage rate of labor is known, Equation (5) can be used to compute the prices of steel and coal. For example, if labor is paid $1,000.00 per man month, then,

$$P_1 = \$615.40$$

$$P_2 = \$830.80$$

If the steel industry charged $615.40 per ton of steel and if the coal industry charged $830.80 per ton of coal, then each industry would receive just enough money to pay its costs.

Some further observations about the prices may be worthwhile. Equation (5) can be condensed by factoring the right hand side and combining the numbers. We have,

$$P_1 = 0.62\ W$$

$$P_2 = 0.83\ W \qquad (6)$$

which shows the prices are directly proportional to the wage rate of labor. The connection between the prices and the labor sector, however, is even more fundamental. The coefficients in Equation (6) are the amount of labor used in the production of both outputs. Each unit of steel delivered to final demand requires 0.62 units of labor and each unit of coal requires 0.83 units of labor. These numbers tell the same story as the interdependency coefficients in Equation (3) except they talk about the primary input, so each coefficient can be computed by the same process shown in Figure 4. The prices, therefore, are directly related to the amount of primary input embodied in each unit of output.

Prices are derived exclusively from the cost considerations of the industries. Labor is one of these costs, but in its role as primary input, it turns out to be the ultimate cost - the ultimate source of value. For this reason, input-output analysis is said to contain a labor theory of value. The prices of steel and coal are not determined by the intersection of a supply and demand schedule in the usual economic sense. Instead, they are determined solely by cost considerations, that is, by supply.

A Forestry Model

A forest management system is a centralized system. An agency or a firm has administrative responsibility for a prescribed area of forest land, so one does not find competing industries under separate management as in the economy. Instead, one generally finds the forestry agency has a budget and a roster of employees. The agency receives guidance from above, from parent agencies with programs of wide scope, and it translates this guidance into specific management action. Many programs are usually adopted, especially if the agency is charged with multiple-use management. The BLM, for example, is interested in timber activities, in harvesting, planting, seeding, and building roads, but it is also interested in grazing activities, recreation activities, and fish and wildlife activities. Other agencies in other parts of the country have similar interests.

Decisions are made at all levels, and the decisions in any particular program often bear consequences in other programs. Some consequences are intended and desirable while others are unintended or undesirable. All the decisions, actions, and consequences result in a set of outputs, a set of goods and services that serve people.

A Two Sector Example

The forestry system just described is different from an economic system, and the corresponding model is also different. The components of the forestry model are not industries and market transactions. Instead, they are activities and decisions.

The activities that replace the industries represent the major forestry programs of the agency being modelled. The flows in a forestry model are results or consequences of decisions. They correspond to the transactions among industries discussed earlier. The primary input is the budget because it provides force and momentum to the activities. The budget is not the only possible primary input, and, as will be mentioned later, alternate choices can provide additional information about the management system. The final demand sector also plays an important role in the forestry model. When a particular resource moves off the forest or is otherwise removed from the forester's control, it is recorded as a flow to final demand. Final demand, then, is not a sector necessarily designating household consumption, but is instead a sector that receives all resources as they leave the forestry system.

The transition from an economy to a forestry system can be illustrated with a simple example. The hypothetical forestry system discussed below uses the same mathematics developed earlier. The example treats a forestry system with two activities, timber and fish. As before, attention is focused on the interactions between the two activities. A flow table of this forestry system is shown as Table 3.

Table 3. Hypothetical Forestry System

	Timber	Fish	Final Demand	Total	Unit of Measure
Timber	0	62	25	87	bf
Fish	43	0	45	88	smolts
Budget	17	35		52	dollars

The timber activity represents the effort and resources needed to harvest mature timber. Its output is measured in board feet (bf). The fish activity designates the efforts of foresters to improve the fish resource of the region, and its output is measured by the number of one year old salmon (smolts) produced. Each activity uses the output of the other. The fish activity uses timber to build structure in the streams that trap and hold spawning gravel. The timber activity causes denuded land which produces excess sediment in the streams and thereby prevents salmon production. The numbers in the table are, of course, hypothetical and they bear no relationships to data found in the literature. But in the Northwest timber and fish activities do influence one another in the ways mentioned, and these influences result from decisions of foresters.[2]

The table says that with the present technology of logging, 43 salmon are prevented from reaching one year's age, that is, the destructive effect of logging 87 bf is that 43 salmon are killed or prevented from hatching. In this sense the logging activity consumes salmon. A similar interpretation can be applied to the flow from timber to fish. To produce 88 smolts, 62 bf are required to help provide spawning gravel.

The flows to final demand in Table 3 are interpreted as products that leave the forestry system. The timber is sold to logging contractors, and the salmon, after one year in the streams, migrate to the ocean. Each of the flows to final demand is interpreted differently from the standard interpretations of the previous section, yet each is consistent with the general explanations given above.

The equations of the forestry system are constructed in the same way as those of the economy. Technical coefficients are computed and used to express total outputs as a sum of individual flows. The

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[2]The problem of estimating the actual magnitude of these influences is not particularly easy, and it will be discussed in the next section.

equations are solved in exactly the same way, and, of course, the final equations on the hypothetical forestry system are identical to those of the economy since the same numbers are used in each example. The interpretation, however, is somewhat more interesting.

The final demand column in the forestry system records the products that leave the forestry production system. Stated another way, these figures are net production, what is left over after the needs of the system have been met. They can therefore be used as production goals. They can be set as desired and feasible, and the equations can be used to predict the total budget required to meet these goals. The individual flows can also be predicted which means managers will gain information about the influences activities are expected to have on one another under planned production goals. And these predictions account for the infinity of derived input requirements discussed in the economy example.

The price analysis discussed earlier also has applications in the forestry system. The fundamental observation behind the price model was that revenues from sales must be just enough to cover the costs. The forestry system does not have markets for all its products, particularly fish in the above example, so the relevant observation simply becomes hypothetical. It is, if the forester charged a price for each output, what price would bring just enough revenue to cover costs. The answer is formulated and solved as before. The price of timber would need to be just high enough to pay for the fish and budget used in production. The price of fish would be enough to pay for the timber and budget. The equations are:

$$P_1 = 0.50\ P_2 + 0.20$$
$$P_2 = 0.70\ P_1 + 0.40 \qquad (7)$$

The solution to this system is:

$$P_1 = \$.62$$
$$P_2 = \$.83$$

If each bf contributed $0.62 and if each year old salmon contributed $0.83, the forestry system would obtain just enough revenues to cover its total budget.

The alternative interpretation applies here also. In the earlier example each unit of steel embodied 0.62 units of labor. In the forestry system each unit of timber embodies 0.62 units of budget, that is, $0.62. This represents the cost of producing each unit of timber. The cost of each fish is $0.83. These costs, like the earlier costs, account for the linked input requirements that are so integral to input-output analysis. The unique feature of these prices is that they arise in the context of a centralized management system. They are derived from the decisions of foresters, and they may be viewed as implications of those decisions.

Applications of the Simple Model

Some examples will help show how the model may be used. Two examples are discussed in the context of the hypothetical forestry system, the first being an application of the quantity system and the second an application of the price system.

In the first example the chief forester of the hypothetical agency plans to increase his timber sale offerings from 25 bf to 35 bf, but he does not want to decrease the yearly migration of salmon. That is, the forester wants to know what total outputs and flows correspond to larger timber offerings and a constant fish migration. It might be noted here that the forester does not control the salmon output to the same degree he controls timber. Salmon spend much of their lives in the ocean and are exposed to aggressive commercial fishing before they reach their spawning areas. The forester has virtually no influence over these parts of a salmon's life, yet events in these periods do influence the size of the spawning migration and subsequent fish production. In this context, the forester is not proposing to administer all the uncontrollable events affecting salmon, but only those he can control. He is asking about more timber production, but he does not want to cause, through events under his control, a decreased salmon production.

The problem can be solved with Equation (3), interpreting it in the context of the forestry system. The new final demand values ($Y_1 = 35$, $Y_2 = 45$) when substituted into the equation, give new total outputs.

$$X_1 = 1.5385\ (35) + 1.0770\ (45) = 102$$

$$X_2 = 0.7692\ (35) + 1.5385\ (45) = 96$$

These new outputs are based on the two goals expressed in the forester's question, and they account for the infinity of linked input requirements described earlier. The outputs can be used in conjunction with the technical coefficients to construct a new flow table.

Table 4. Resource Flows with New Final Demands

	Timber	Fish	Final Demand	Total	Unit of Measure
Timber	0	67	35	102	bf
Fish	51	0	45	96	smolts
Budget	20	38		58	dollars

Table 4 shows that both the salmon and timber outputs are larger. More timber production causes more sediment in the streams which, in turn, kills more salmon. The fish flow to timber increased from 43 (see Table 3) to 51. To offset the fish loss, an additional 5 bf were used to improve the spawning habitat, and the flow of timber to fish increased from 62 (see Table 3) to 67. The total output of timber increased by 15 bf, 10 of which are part of the new final demand and 5 of which are used to bolster the fish activity. The total output of fish increased from 88 (see Table 3) to 96, an increase equal to the additional fish 'consumed' by logging. The chief forester can also see that a higher budget is needed to support the increases in each activity. The question posed by the chief forester in this example is difficult, yet the model gave very specific answers.

A second example will illustrate how the prices can be used to help evaluate management plans. Instead of a change in the level of output, the chief forester will now consider a policy change with respect to logging. He is interested, say, in protecting fish habitat from the impacts of logging, and he proposes that all logging contractors leave a buffer strip of vegetation along streams. He turns to his staff for an analysis of this proposal.

As before, the new policy must be stated in the language of input-output models. The policy does not necessarily alter the level of output, but, instead, it changes the structure of the system, the technical coefficients. Since the intent of the policy is to protect fish, the timber reserved in the buffers is recorded as a flow to fish. The chief foresters' staff estimates, say, that the technical coefficient from timber to fish will increase from 0.70 to 0.75. The policy will also reduce stream damage which implies a smaller fish loss. Suppose the technical coefficient from fish to timber is expected to decrease from 0.50 to 0.45. Assume the budget coefficients remain unchanged. Table 5 shows the new structure.

Table 5. Technical Coefficients Under Proposed Policy

	Timber	Fish
Timber	0	0.75
Fish	0.45	0
Budget	0.20	0.40

The new coefficients lead to new price and quantity equations. The procedure is identical to that described earlier, and the computations are omitted here. The new prices are,

P_1 = \$.57

P_2 = \$.83

The price of fish is still \$0.83, but the price of timber has decreased from \$0.62 to \$0.57. The decrease means each board foot will cost less if the policy is adopted. If the chief forester undertakes the proposed policy and does not change his levels of production, the budget will decrease. That is, the decision to adopt the new policy implies a lower cost technology. Another point can also be made. The chief forester, if he adopts the policy, will change his relative emphasis (or at least one measure of it) between the two activities. He would be emphasizing the attributes of fish more than he had in the past. The price changes are a measure of this changed emphasis.

The forestry staff can present this information to the chief, who will use it, along with the results of another analysis, to decide the fate of the proposed policy.

Information of this type is not always derived as easily as the example may suggest. For example, if the forestry staff had estimated a more drastic increase in the timber to fish coefficient, say to 0.80, the prices would have been,

P_1 = \$0.59

P_2 = \$0.88

In this case the price of timber is lower, but the price of fish is higher. This means the new technology is not necessarily one of lower cost. It is possible, however, to say something,about management emphasis. If the policy is adopted, then the forester is putting an even stronger emphasis on fish. The new technology reduces the budget intensity of timber and increases the budget intensity of fish.

The Eugene Model

The Eugene District

The Eugene District, one of five in western Oregon, includes over 300,000 acres of land, much of which is heavily forested with mature Douglas Fir. The lands are part of the O & C grant lands and are arranged in the well-known checkerboard pattern. The ownership pattern creates problems for the Bureau--problems of access and other problems associated with intense public interest in Bureau management. Three major rivers, the Siuslaw, McKenzie, and Willamette, flow through the district. Each provides excellent opportunities for fishing and other

forms of water recreation. All three of the rivers have large salmon migrations which provide exceptional fishing for local residents. The district has other wildlife resources also. Deer, elk, and bear inhabit the region as well as many small game species. The district also maintains several recreation sites, most of which offer swimming, camping and picnic facilities. Logging is another important activity on the district especially since many stands have volumes in excess of 60 Mbf per acre. The district's allowable cut is 219 million board feet per year, and this timber is an important determinant of local economic activity.

The Bureau manages its lands in accord with the principles of sustained yield and multiple use. It aims at producing a stable level of wood harvest and at maintaining wildlife and fish populations. The Bureau is also subject to continual lobbying pressures from industrial organizations and environmental groups. The scope of the Bureau's work and the pressure under which it operates make its task very complicated. It deals on the one hand with biological systems of great variability and on the other with a vastly complex social system. The Bureau must use these resources to fashion a set of policies and programs that represent, in some sense, an optimum. The specific activities the Bureau undertakes to achieve its goals are described below.

The Model

The most basic components of the model are the sectors, and they correspond to the major activities of the Eugene district. The activities are concerned with five general resource programs; timber, wildlife, recreation, roads, and air and water pollution. All the activities included in the model are shown on the borders of Table 6.

Table 6 is interpreted just like Table 1, Table 3, and Table 4. The numbers in each column are inputs and those in each row are outputs. Some of the units are multiplied by 100 or 1000 to eliminate rounding error in the computations. For example, the output of 10' road construction is miles x 1000, that is, the total output is 23,500 thousandths of a mile, or 23.5 miles.

The data in Table 6 were gathered in the summer of 1970. The Bureau's records provided most of the data, but other sources, including foresters' estimates, were also used. Some data were obtained directly from published scientific work, and, of course, many of the estimates rely simultaneously on all these sources. The part that each source played will become more clear below, where the flows are discussed and interpreted. The remainder of this section is devoted to that task.

Table 6. FLOW DATA, F.Y. 1969

Consuming Sector / Producing Sector	Old gr. har.	Old gr.	Young gr.	Com. thin.	Mort. & salv.	Seeding	Planting	Fish const.	Fish	Deer	Rec. const.	Ext. rec.	Rec. maint.	10' Rd. const.	12' Rd. const.	20' Rd. const.	Rd. maint.	Air Service	Water Service	Final demand	Total Output	
1. Old growth harvest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160949	160949	Mb.f.
2. Old growth	160949	-	-	-	27023	-	-	-	-	-	1665	64314	-	-	-	-	-	-	-	-	253951	Mb.f.
3. Young growth	-	-	-	8005	-	-	-	-	-	-	205	4434	-	-	-	-	-	-	-	-	12644	Mb.f.
4. Commercial thinning	-	-	6300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1705	8005	Mb.f.
5. Mortality and Salvage	-	20839	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6184	27023	Mb.f.
6. Seeding	-	-	348840	-	-	-	95299	-	-	199579	-	-	-	-	-	-	-	-	-	-	643718	seedling
7. Planting	-	-	737865	-	-	-	40820	-	-	310541	-	-	-	-	-	-	-	-	-	-	1089226	seedling
8. Fish construction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	800	800	gabion x 100
9. Fish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6414	216659	223073	smolt
10. Deer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1805	1805	harvested deer
11. Recreation construction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1000	1000	campsite x 1000
12. Extensive recreation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2101	2101	acres
13. Recreation maintenance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20897	20897	visitor day
14. 10' Road construction	23500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23500	mile x 1000
15. 12' Road construction	5700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5700	mile x 1000
16. 20' Road construction	-	-	-	-	-	-	-	-	-	-	1000	-	-	-	-	-	-	-	-	7000	8000	mile x 1000
17. Road maintenance	447200	-	-	5500	17200	13200	13200	-	13200	13200	-	-	-	-	-	-	-	-	-	142200	664900	AYT[1] x 100
18. Air service	131627	-	-	1409	5140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	138176	ton
19. Water service	171100	-	-	1800	6600	-	-	-	-	-	-	-	-	290130	70560	99810	-	-	-	-	640000	ton x 100
20. Budget	320297	-	2001	22761	82515	34204	73729	7365	-	604	22307	1814	19503	111362	27065	518536	334383	-	-	-	1578446	dollar
21. Labor	356.7	-	2.1	19.0	68.8	14.1	28.9	10.1	-	0.6	17.5	2.1	24.5	119.9	29.2	28.0	16.5	-	-	-	738.0	man month

The timber sale and subsequent harvest are the focus for many of the activities on the district. These volumes are recorded as flows to final demand. Old growth harvest is the largest of these flows (160,949 Mbf), but the thinning (1,705 Mbf) and salvage (6,184 Mbf) volumes are also important. Thinning and salvage cuttings have residual timber on the site, and these volumes are shown as flows to young growth (6,300 Mbf) and old growth (20,839 Mbf) respectively.

The growth sectors serve an accounting function. They deliver standing timber to the harvesting sectors and, as mentioned, receive the residual stands. In addition, they deliver timber to the recreation sectors, timber that will not be cut because of its value for recreation. The flows to recreation construction (1665 Mbf and 205 Mbf) are timber on buffer strips around recreation sites. Those to extensive recreation (64,314 Mbf and 4,434 Mbf) are timber on sites with high scenic value. Neither of the growth sectors deliver to final demand.

The reforestation sectors deliver seedlings to three sectors. Most are delivered to young growth where they will mature. Others occupy sites that are insufficiently stocked and are scheduled for replanting. Many other seedlings are delivered to deer, that is, deer eat the trees.

The reforestation sectors provide a good illustration of data sources and problems. The total number of seedlings planted is recorded by the Bureau. This is a reliable number. The amount of seedlings returned to planting, however, is not reliable. The Bureau knows the acreage involved, but it does not have good records on the average stocking of these areas. Expert opinion, the estimates of several field foresters in Eugene, filled this gap. Lastly, the flow to deer was computed from information in a progress report of The Cooperative Animal Damage Survey Committee, a group organized in the Pacific Northwest to study the impact of animal damage on forest plantations.[3]

The fish construction sector delivers all its output to final demand. The output of this activity is gabions, large wire cages filled with rocks. When placed in a salmon spawning area they trap and hold gravel that would otherwise wash downstream. Migrating salmon lay their eggs in the gravel, so the gabions provide additional spawning areas for salmon. The output of the fish sector is 1-year-old coho salmon (smolts). After rearing for a year in the streams,

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[3]CADS Committee, Third Progress Report of the Cooperative Animal Damage Survey of Forest Plantation in Oregon and Washington. Unpublished draft, 1969.

these salmon move downstream to the ocean, where they mature and return later to spawn. This migration is recorded as an entry in the final demand column. The estimate is based largely on data from the Oregon State Game Commission. The fish flow to water service (6,414 fish) is an estimate of the fish loss from logging and road construction, about which more is said below. The deer sector delivers its total output to final demand, and it is an estimate of hunter kill on Bureau land.

The three recreation sectors record the Bureau's accomplishments in its recreation program. The construction sector measures the number of campsites constructed in a year and the extensive recreation sector measures the acreage set aside for scenic purposes. The recreation maintenance sector provides visitor days of recreation which are consumed by the public. No other sector uses the outputs of the recreation sectors, and their outputs are delivered to final demand.

Three road construction sectors account for the roads built on the district. In 1969, 23.5 miles of 10' road were constructed to harvest timber, and this mileage is shown as a flow to old growth harvest. All those roads were built as part of timber harvesting activities. The largest roads on the district are built from appropriate monies, and construction is administered by the Bureau of Public Roads. They are the main arteries of the district's access system and they are not designed for a special purpose. Seven miles were built in 1969, and they are shown as a flow to final demand. In addition, approximately one mile was constructed for a recreation site, and it is shown as a flow to recreation construction.

The output of the road maintenance sector records the vehicle use associated with each of the other sectors. These flows were derived from traffic data in the Bureau's records. The flow to final demand, (1422 vehicles per year) is an estimate of public use of Bureau roads.

The air service sector records the tons of slash burned on the district during 1969. Only the logging operations contributed to the smoke pollution, so there are three entries, one for each harvesting sector. The water service sector records the sedimentation from logging and road construction. The streams provide the service of receiving sediment, and this service is an input to the logging and road construction activities. As a result of the sediment, fish are prevented from hatching and the fish loss is recorded as an input to water service (6,414 fish) as mentioned above.

The amounts of budget and labor flowing to each activity represent the money and man months spent in each category in 1969. These are the primary inputs to the model.

One of the most notable features about the flow table is the unusually large number of blank spaces. If one takes the view that everything is related to everything else, all the blanks should be replaced with some numerical flow. In fact, either the relationships simply aren't known with enough certainty to warrant their inclusion in the table, or the model impedes the use of existing information. For example, there is surely a relationship between recreationists and old growth - people enjoy virgin forests. There is no way, however, to include these preferences in the model. They would be recorded as a flow from old growth to one of the recreation sectors, but thousands of board feet, the unit of output of old growth, is clearly an inadequate unit for representing such a relationship. People do not measure their enjoyment in terms of board feet. Unfortunately no known procedure can solve this problem.

Table 6 also tells a story about the knowledge foresters have accumulated. Foresters have studied trees for years, yet only recently have other forest resources been the subject of serious study. Their knowledge in other areas is fragmentary compared to their knowledge of timber management. This too, is evident in the flow table. The non-timber sectors contain more zeros, reflecting the general ignorance of professional foresters. Had the Bureau originally been directed to emphasize fish and wildlife management, the general distribution of ignorance throughout the table would probably be much different.

The flow data shown in Table 6 are used to build a system of equations like those presented in previous chapters. The only differences between the Eugene model and the hypothetical model is size. Instead of 2 equations, the Eugene Model has 20, and the equations are solved by a computer. But the interpretations of the results are the same in both cases. The results of the computer analysis are shown in Tables 7 and 8.

Table 7 shows the technical coefficients associated with the flows in Table 6. Each coefficient is a per unit input requirement, i.e., each is computed by dividing a flow of Table 6 by the total output of the column sector. For example, the technical coefficient in row 4, column3 is 0.4983, which equals 6300/12644. The units of both sectors involved are, in this case, Mbf, so the coefficient says that each unit of total output of young growth is associated with 0.4983 units of residual timber from commercial thinning.

Table 8 shows the interdependency coefficients which result from the solution of the production equation. Each shows the change in the total output of one sector associated with a one unit change in the final demand of another sector. The total outputs are identified by row, and final demands are identified by column. For example, the coefficient in row 7, column4 is 120.8393 which means that, given the conditions of 1969, every additional thousand board feet of commercial thinning requires a total increase in planting

Table 7. TECHNICAL COEFFICIENTS, F.Y. 1969

Consuming Sector	Old gr. har.	Old gr.	Young gr.	Com. thin.	Mort. & salv.	Seeding	Planting	Fish const.	Fish	Deer	Rec. const.	Ext. rec.	Rec. maint.	10' Rd. const.	12' Rd. const.	20' Rd. const.	Rd. maint.	Air Service	Water Service
Producing Sector																			
1. Old gr. har.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Old gr.	1.0000	-	-	-	1.0000	-	-	-	-	-	1.6650	30.6111	-	-	-	-	-	-	-
3. Young gr.	-	-	-	1.0000	-	-	-	-	-	-	0.2050	2.1104	-	-	-	-	-	-	-
4. Com. thin.	-	-	0.4983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Mort. & salv.	-	0.0821	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Seeding	-	-	27.5894	-	-	-	0.0875	-	-	110.5701	-	-	-	-	-	-	-	-	-
7. Planting	-	-	58.3569	-	-	-	0.0375	-	-	172.0449	-	-	-	-	-	-	-	-	-
8. Fish const.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. Fish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0100
10. Deer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. Rec. const.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Ext. rec.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13. Rec. maint.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. 10' Rd. const.	0.1460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. 12' Rd. const.	0.0354	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16. 20' Rd. const.	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-	-	-
17. Rd. maint.	2.7785	-	-	0.6871	0.6365	0.0205	0.0121	-	0.0592	7.3130	-	-	-	-	-	-	-	-	-
18. Air service	0.8178	-	-	0.1761	0.1902	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19. Water service	1.0631	-	-	0.2249	0.2442	-	-	-	-	-	-	-	-	12.3460	12.3790	12.4763	-	-	-
20. Budget	1.9901	-	0.1583	2.8434	3.0535	0.0531	0.0677	9.2062	-	0.3346	22.3070	0.8634	0.9333	4.7388	4.7483	64.8170	0.5029	-	-
21. Labor[1/]	0.0022	-	0.0002	0.0024	0.0026	0.219E-4	0.265E-4	0.0126	-	0.0003	0.0175	0.0010	0.0012	0.0051	0.0051	0.0035	0.248E-4	-	-

1/ Some labor coefficients are shown in scientific notation; for example, 0.219E-4 = 0.0000219.

Table 8. INTEROEPENOENCY COEFFICIENTS, F.Y. 1969

Consuming Sector / Producing Sector	Old gr. har.	Old gr.	Young gr.	Com. thin.	Mort. & salv.	Seeding	Planting	Fish const.	Fish	Deer	Rec. const.	Ext. rec.	Rec. maint.	10' Rd. const.	12' Rd. const.	20' Rd. const.	Rd. maint.	Air Service	Water Service
1. Old growth harvest	1.0000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Old growth	1.0894	1.0894	-	-	1,0894	-	-	-	-	-	1.8138	33.3476	-	-	-	-	-	-	-
3. Young growth	-	-	1.9931	1.9931	-	-	-	-	-	-	0.4086	4.2063	-	-	-	-	-	-	-
4. Commercial thinning	-	-	0.9931	1.9931	-	-	-	-	-	-	0.2036	2.0958	-	-	-	-	-	-	-
5. Mortality and Salvage	0.0894	0.0894	-	-	1.0894	-	-	-	-	-	0.1488	2.7365	-	-	-	-	-	-	-
6. Seeding	-	-	65.5606	65.5606	-	1.0000	0.0909	-	-	126.2101	13.4399	138.3604	-	-	-	-	-	-	-
7. Planting	-	-	120.8392	120.8393	-	-	1.0389	-	-	178.7460	24.7720	255.0216	-	-	-	-	-	-	-
8. Fish construction	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-	-	-	-	-	-
9. Fish	0.0333	0.0002	0.0022	0.0045	0.0027	-	-	-	1.0000	-	0.1259	0.0114	-	0.1237	0.1241	0.1250	-	-	0.0100
10. Deer	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-	-	-	-
11. Recreation construction	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-	-	-
12. Extensive recreation	-	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-	-
13. Recreation maintenance	-	-	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-	-
14. 10' Road construction	0.1460	-	-	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	-
15. 12' Road construction	0.0354	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-
16. 20' Road construction	-	-	-	-	-	-	-	-	-	-	1.0000	-	-	-	-	1.0000	-	-	-
17. Road maintenance	2.8374	0.0569	3.4912	4.1784	0.6936	0.0205	0.0145	-	0.0592	12.0672	0.8179	9.1101	-	0.0073	0.0073	0.0074	1.0000	-	0.0006
18. Air service	0.8348	0.0170	0.1748	0.3509	0.2072	-	-	-	-	-	0.0642	0.8895	-	-	-	-	-	1.0000	-
19. Water service	3.3259	0.0218	0.2233	0.4481	0.2661	-	-	-	-	-	12.5584	1.1396	-	12.3460	12.3790	12.4763	-	-	1.0000
20. Budget	4.5500	0.3016	16.5579	19.7469	3.6753	0.0635	0.0824	9.2062	0.0298	25.2087	91.0243	45.0396	0.9333	4.7425	4.7519	64.8208	0.5029	-	0.0003
21. Labor	0.0034	0.0002	0.0074	0.0098	0.0028	0.224E-4	0.229E-4	0.0126	0.147E-5	0.0081	0.0229	0.0237	0.0012	0.0051	0.0051	0.0035	0.248E-4	-	0.153E-7

1/ Some labor coefficients are shown in scientific notation; for example, 0.224E-4 = 0.0000224.

of 120.8393 seedlings. Just as in the earlier hypothetical models, the Eugene model has more interdependency coefficients than technical coefficients. Many sectors, though not directly related to one another by flows, are linked by the indirect affects shown in the interdependency coefficients. This information is useful because it shows managers how the consequences of their decisions influence other activities.

Applications

Input-output analysis can be applied in several ways to the problems of resource managers. Taken together, the applications address a wide range of interests, and in any particular case, a problem may be explored in great detail. The principal areas of application are:

1. Evaluating decisions
2. Allocating primary inputs
3. Planning the short run
4. Planning the long run
5. Planning research
6. Training

Each is discussed below.

Evaluating Decisions

One of the Bureau's aims is to have its daily decisions be consistent with its broader goals and policy. Policies are formulated in the legislature and at the upper levels of the Department of Interior, and field level decisions must reflect these policies. The agency's decisions must be coordinated over time, and at any time, decisions must be coordinated among the agency's subdivisions. The prices derived from the Eugene model reflect the Bureau's decisions, and they can be used, in conjunction with other prices, to evaluate decision consistency. Table 9 contains the prices. As discussed above, two primary inputs are used alternately in the model, so two sets of prices are shown. The direct budget expenditures are the technical coefficients shown in rows 20 and 21 of Table 7. They are the amounts of money and labor the Bureau allocated directly to each activity. The labor entries in Table 9 are multiplied by the average cost of a man-month in FY 69 ($961.00) to make them comparable to the dollar entries.

The best way to measure the Bureau's consistency is to use a series of prices like those shown in Table 9. The Bureau does not now have series of prices, and to get them, they would need input-output models for several consecutive years or for several different districts. The time series of prices would allow the Bureau to

monitor decisions over a series of years. For example, the price of fish may increase over the years as a result of new programs in fish management. The Bureau may decide that the programs are too expensive and discontinue them, or it may find that the benefits derived from the fish resource are indeed great enough to offset the increased costs. In another case, the prices of outputs may fluctuate markedly over the years, and the Bureau, after looking into the matter, may find that frequent personnel changes caused erratic decision making. The Bureau might then undertake policies designed to stabilize district management.

A similar stragegy could be used to coordinate decision making among districts. The price of timber in one district may be $3.00 while all the other districts have timber prices near $4.55 as in Eugene. The Bureau may well find that the low cost district has been selling timber in already roaded areas, whereas the other districts are selling timber in undeveloped areas. Road building affects the timber value because roads are an input to old growth harvest. If the Bureau had a policy to leave roadless areas undeveloped until allowable cut requirements could not be met from developed areas, then the other districts would want to alter their management practices to conform to the policy.

Allocating Primary Inputs

The prices in Table 9 can be used to discover which activities are relatively budget intensive and which are relatively labor intensive. An understanding of how primary inputs are used in each activity can help the Bureau plan programs in years when one of the inputs is relatively scarce. For example, the Bureau has recently been operating under very restrictive manpower ceilings, so it may well want to emphasize activities that economize on the use of labor.

Such activities can be found by forming price ratios between activities. The labor price ratio between recreation construction and another activity, say 12' road construction, is 22.01/4.93 = 4.46, while the corresponding budget price ratio is 91.02/4.75 - 19.16. Relative to 12' road construction, recreation construction uses approximately four times more budget than labor. The source of the budget intensity can be traced to its origins by inspecting Tables 8 and 9. Column 11 of Table 8 shows the sectors that provide inputs to recreation construction (both direct and indirect). The budget intensity of each of the related sectors can be found by examining the first two columns of Table 9. Of the eleven sectors that interact with recreation construction, six of them use relatively less labor than budget. The other five use equal amounts per unit of output. In a period, then, when manpower ceilings are restrictive, the Bureau may well choose to undertake activities like recreation construction, activities that are budget intensive.

Table 9. DIRECT COSTS AND PRICES OF BLM OUTPUTS, F.Y. 1969

		Direct Expenditure		Prices		
	Sector	Budget	Labor	Budget	Labor	Unit of Output
1.	Old gr. har.	$ 1.99	$ 2.13	$ 4.55	$ 3.30	Mb.f.
2.	Old gr.	0.0	0.0	0.30	0.22	Mb.f.
3.	Young gr.	0.16	0.16	16.56	7.13	Mb.f.
4.	Comm. Thin.	2.84	2.28	19.75	9.43	Mb.f.
5.	Mort. & Salv.	3.05	2.44	3.68	2.68	Mb.f.
6.	Seeding	0.05	0.021	0.06	0.022	Seedling
7.	Planting	0.07	0.025	0.08	0.029	Seedling
8.	Fish const.	9.21	12.13	9.21	12.13	Gabion x 100
9.	Fish	0.0	0.0	0.03	0.0014	Smolt
10.	Deer	0.33	0.32	25.21	7.82	Harvested deer
11.	Rec. const.	22.31	16.82	91.02	22.01	Campsite x 1000
12.	Ext. rec.	0.86	0.96	45.04	22.74	Acre
13.	Rec. maint.	0.93	1.13	0.93	1.13	Visitor day
14.	10' Rd. const.	4.74	4.90	4.74	4.90	Mile x 1000
15.	12' Rd. const.	4.75	4.93	4.75	4.93	Mile x 1000
16.	20' Rd. const.	64.82	3.36	64.82	3.36	Mile x 1000
17.	Rd. maint.	0.50	0.024	0.50	0.024	AYT x 100
18.	Air service	0.0	0.0	0.0	0.0	Ton
19.	Water service	0.0	0.0	0.0003	0.15E-4 [1/]	Ton x 100

[1/] 0.15E-4 = 0.000015.

The prices can also be used to identify activities that use relatively low cost labor. If the Bureau decided in future years to emphasize some of these activities, it would also want to upgrade the quality of labor embodied in the activities. The Bureau may also want to compare these activities among districts and over time as discussed in the first application, but these comparisons would require models for each district over several years.

The activities are found by forming ratios of labor prices to budget prices within activities. The ratios should be less than 1.0 because the budget figures include money spent on wages as well as money for other materials. This results from the Bureau's record keeping system. The labor prices were computed by multiplying the average cost of a man month of labor in Eugene ($961.00) by the labor embodied in each unit of output, and if the average cost were correct in each activity, the ratios would never be greater than 1.0. But in fact some of the ratios are greater than 1.0 (Fish construction is an example where the labor/budget ratio is 12.13/9.21 = 1.32), which means the $961.00 is incorrect for those sectors. Since the correct cost would give a ratio less than one, the $961.00 is too high, that is, the actual cost of labor in those sectors is less than average. Four sectors can be identified from the FY 69 data as employing inexpensive labor: fish construction, recreation maintenance, 10' road construction, and 12' road construction.

Planning the Short Run

Two types of applications are relevant to the Bureau for short-run planning. The first involves planning program packages. An example of this application was discussed earlier as the first application of the simple model. The interdependency and technical coefficients can be used to predict the total outputs, flows, and primary inputs corresponding to any vector of final demands. These predictions can help the Bureau prepare annual work plans and justifications for budgets. For example, the district may want to increase its timber harvest, decrease its recreation construction activity, and increase the fish construction activity. These proposals can be tested in the model by substituting the appropriate numbers in the final demand column. The model will then predict the total outputs of all the sectors, the interactivity flows, and the budget and labor needed to support the new programs.

The advantage of the model in making these projections is that it accounts for the linkages between activities. The effect of these linkages can be demonstrated with a 5% increase in the output of old growth harvest. The model predicts a budget increase of 2.3% is needed to fund the increased cutting. The same calculation can be made using only the account for old growth harvest (before the linkages are accounted for), and that projected increase is 1.0%. The latter calculation does not include the effects of increased road

construction, road maintenance, and mortality cutting. The influence that old growth harvest exercises on these other activities is included in the interdependency coefficients.

A second application in the area of short-run planning is evaluating changes in the structure of decision making. The tables of flows and coefficients shown above are appropriate to the policies and procedures used in Eugene in 1969. The Bureau changes its procedures frequently, and these changes affect the coefficients. When such changes are being considered, the input-output model can be used to help evaluate them. This application is distinct from the first one in the area of short-run planning because the first considers changes in the level at which activities are run while this one considers changes in the way activities are conducted.

For example, the Bureau has recently decided to leave a buffer strip of vegetation along streams in logging areas. This policy change can be analyzed in the Eugene model just as it was in the simple two-sector model. The following changes must be incorporated into the model. First, the timber reserved in the buffer strips is entered as a flow from old growth to fish. The amount (1136.7 Mbf) is estimated from data in the FY 69 timber sale contracts. Second, the sediment discharged from the logging areas is reduced because of the buffers, and the reduction is estimated to be 65%. That is, the amounts of water service used by the logging sectors is decreased from those shown in table 6 by 65%. Third, since the destruction of fish habitat is reduced, the flow of fish to water service is also reduced, that is, the fish kill is smaller. When the changes are incorporated in the equations and the system is solved on the computer, two conclusions can be drawn as guides for decisions. First, the model predicts the fish loss from logging will be reduced by 59%. Second, the buffer strip program affects the Bureau's costs only negligibly as monitored by the prices. The only prices affected are the price of fish (which rose from $0.0298 to $0.0313) and the price of water service (which declined from $0.0003 to $0.00014), but the effect of these small changes is negligible. This information helps justify the decision to maintain buffers because the fish loss is reduced and effect on the budget is negligible.

Planning the Long Run

Long-run plans are those with a horizon of more than five years. As the Bureau envisions new activities or whole new technologies it can translate these visions into flow data and process them through the model. The results would show the technical coefficients, interdependency coefficients, and prices for future technologies. The interdependency coefficients help foresters foresee the district wide impacts of alternative technologies, and the prices show the relative emphasis the Bureau places on its management programs.

An input-output model interacts well with other planning procedures used by the Bureau, including the allowable cut model. The allowable cut model calculates information about the growth and yield of a forest for a several hundred year period. Since the forests in western Oregon are being converted from old growth to second growth and since the Bureau also intends to intensify its timber management programs, the structure of the forest will change markedly over the decades. The results of the allowable cut model can be used to build an input-output model for a specified future timber period. What follows is a summary of how this can be accomplished.

The first decade, up to 1980, was chosen as the period for an input-output model. The model is intended to describe a representative year in that decade. In the first decade the Eugene district is scheduled to begin precommercial and commercial thinning on a large scale and to do regeneration cutting in young stands (less than 140 years old). The timber system is more complex in 1980 than in 1969, but not as complex as is expected in 1990 or 2000. The flow entries concerning the timber program were calculated from the allowable cut forecasts. The data for the other sectors were forecast independently.[4]

The 1980 model indicates the Bureau is planning to emphasize timber production in the future. This conclusion is based on the prices associated with the FY 1980 model which are shown in Table 10. Excepting young growth and commercial thinning, the prices associated with allthe timber sectors present in the FY 1969 model increased, while the prices of other sectors remained largely unchanged. This means the Bureau's budget will be more heavily concentrated in timbe activities in the future. These conclusions are not surprising if the data are considered. Increases in timber management efforts are included in the allowable cut, but no large scale, comprehensive program for the development of other resources is under consideration. The model, then, is only telling a story implicit in the data.

Planning Research

One of the virtues of an input-output model is it demands detailed information about the major activities. The model synthesizes the information and makes it relevant to problems facing resource managers. Guides for research planning and information gathering are inevitable by-products of working with the model. Each of the cells in Table 6 represents a potential research project,

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[4] The flows and coefficients for the 1980 model are discussed in more detail in, Flick, Warren A., Resource Valuation and Multiple Use Planning: An Input-Output Approach. USDI, Bureau of Land Management, Guides to Land Management Report No. 15, December 1972.

Table 10. BUDGET AND LABOR PRICES, F.Y. 1980.

1.	Old gr. har.	$ 4.93	$ 3.54	Mb.f.
2.	Young har.	10.37	6.47	Mb.f.
3.	Old gr.	0.68	0.45	Mb.f.
4.	Young gr.	6.12	3.38	Mb.f.
5.	Ov. yng. gr.[1/]	0.02	0.01	Tree
6.	Precom. thin.	0.05	0.02	Tree
7.	Com. thin.	12.04	7.19	Mb.f.
8.	Mort. & Salv.	5.89	3.90	Mb.f.
9.	Seeding	0.06	0.022	Seedling
10.	Planting	0.08	0.03	Seedling
11.	Fish const.	9.19	12.13	Gabion x 100
12.	Fish	0.04	0.005	Smolt
13.	Deer	25.12	7.77	Harvested deer
14.	Rec. const.	89.51	21.62	Campsite x 1000
15.	Ext. rec.	34.54	21.87	Acre
16.	Rec. maint.	0.93	1.13	Visitor day
17.	10' Rd. const.	4.74	4.90	Mile x 1000
18.	12" Rd. const.	4.75	4.93	Mile x 1000
19.	20' Rd. const.	64.82	3.36	Mile x 1000
20.	Rd. maint.	0.50	0.024	AYT x 100
21.	Air service	0.0	0.0	Ton
22.	Water service[2/]	0.16E-3	0.29E-4	Ton x 100

[1/] Overstocked young growth

[2/] Prices are shown in scientific notation; for example, 0.16E-3 = 0.00016.

and, if undertaken and completed, the results are guaranteed relevant. They can be used immediately in the model, improving the basis for Bureau decisions.

For example, the model includes estimates of deer damage to seedlings and the estimates take a particular form - the number of seedlings eaten. The estimates were derived from tentative research results and expert opinion on the Eugene district. Future research could be designed to improve these estimates, and the better the estimates, the more reliable will be the model's forecasts.

Other research could be aimed at aspects of the forestry system not now included in the model. Bear damage is reported at times to be significant in Douglas fir stands, yet useable estimates of the extent of this damage were not found. Again, research could be aimed at getting such estimates, and a bear sector could then be included in the model. Similar data problems were encountered when the fish resource was examined. The present data includes information only on coho salmon, but further research could provide data on other important species.

Training

An input-output model shows all the activities integrated into a whole, so it helps foresters see specific actions in the context of the whole district management program. This feature makes it ideal for on-the-job training programs. A training program that employs the model could give two results: the participants would learn to see their individual responsibilities in the context of the total forestry program, and they would learn to use a tool that aids management planning. A two or three day program aimed at these results could be organized around several case studies. Bureau managers could be separated into groups, each doing a different case. Near the end of the session each group could present a summary of its work and recommend policies based on the analysis. This training program would require each participant to concentrate simultaneously on the individual activities and the role each plays in the district. This emphasis on integration is important, especially since most foresters work for extended periods of time in specialized areas.

Conclusions

The first conclusion is that input-output models are certainly feasible for analyzing multiple-use systems. It is possible to specify an appropriate model, gather the data, and solve the equations. The results are interpretable and reasonable. Moreover, the data needed to construct and maintain the model are relatively inexpensive which means that as the forestry system changes, the model can be easily updated.

A second general conclusion is that input-output models have a variety of applications in forestry. Six major categories are outlined above, and each contains several different possibilities. This makes the technique attractive to potential users because the high degree of flexibility raises the likelihood of successful applications.

A third conclusion involves a forecast about future land management practices. As forest management becomes more intensified, the interactions among activities will increase, and the attractiveness of a model that explicitly analyzes the interactions will also increase. Therefore, the procedures should be tested in other locations and with other agencies, and they should be applied to a variety of resource systems.

Summary

The problems associated with multiple-use planning are complex because decision makers must deal simultaneously with many different programs. The Bureau of Land Management faces these problems daily in western Oregon where it manages over two million acres of lush forests. Input-output analysis was used to model the Bureau's forest management system, and the results provide specific information to be used in the context of multiple use management.

Input-output models emphasize production. They are used by economists to study the general interdependence among industries that exists in all developed economies. The model is essentially two sets of equations, one describing the transactions that occur among industries, and one describing the value relations that result from the transactions. The equations are used for prediction. The first set, those of the transactions, predict specific changes in the level of economic activity, specific to the industries of the economy, that are caused by varying levels of household consumption. Consumers, then, play an important role in the model; they provide momentum to the economy through their demands, and they are the last receivers of all the goods and services produced. The second set of equations, the value equations, assign prices to all the products of the economy. The assignments are made on the basis of the flows of products occurring among the industries. Ultimately, the value of each product is dependent on the amount of primary input, usually labor, employed in each industry. Since labor is the ultimate source of value in input-output models, they are said to embrace a labor theory of value.

When used to model a multiple use forestry agency, the model assumes a different character. The industries and transactions that are so integral to the economy model are replaced by activities and decisions. The agency's activities, taken together, represent

all the major resource programs on the forest. The decisions made in any program may well affect other programs, and these effects are built into the forestry model must as are the transactions in the economy model. The equations of the forestry model have the same formal properties as their economy counterparts, but the interpretations and applications are different. The final demand sector is viewed as a sector of production goals, and the model predicts the budget and labor, and the interactivity affects implied by any set of production goals. The unique feature of the predictions is that they account simultaneously for all the interactivity affects that can be built into the model. The forestry model also has value equations. Most of the products of the forest are non-market items like deer, fish, road construction, seedlings, and so on. The forestry value relations can be traced through the system, just as in the economy case, to the amount of primary input used by each activity. The budget is the primary input in the forestry system because the budget gives force and meaning to the many activities. The prices assigned to the forest's products, then, are the budget embodied in each output.

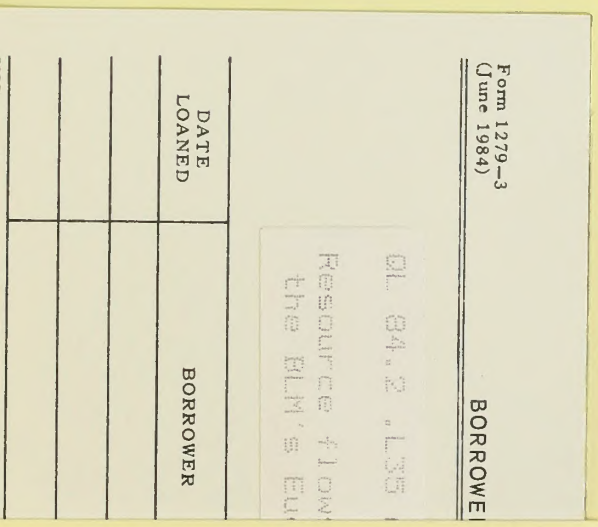
Input-output analysis was tested in the Eugene District of the Bureau of Land Management. Twenty-one sectors describe the Bureau's management system. Timber, reforestation, fish, deer, recreation, access, and pollution programs are included in the model, each having a different number of sectors. The data were gathered in the summer of 1970, and they apply to fiscal year 1969. The model was programmed and solved on a computer, and the principal results are a set of quantity equations which characterize the interactivity affects and a set of value equations which assign prices to all the Bureau's outputs.

The model has several promising applications for multiple-use planning. First, the prices may be used to evaluate the emphasis placed by the Bureau on its several programs. The Bureau's budget is a decisionable entity, so the prices reflect implications of current decisions. If models are constructed for several districts over several years, the prices can measure the consistency of decisions among districts and over time. These measures provide a basis for regulating forestry practices to meet prescribed goals - value goals. The prices also show which activities are relatively budget and labor intensive, providing guides for resource allocation in years when either money and/or labor is relatively scarce. The prices can also be forecast for future years, providing insight into the value relations toward which the Bureau is moving.

Second, the model can be used for short-run planning. Alternative programs can be expressed in the model, and the short-run district-wide impacts of these programs can be predicted. Tested programs may include changes in the levels at which activities are run or changes in the technology of the system. Third, the model can be used for long-run planning. The flow data can be forecast to future years and the model will show the interdependency coefficients and prices appropriate to that time. Both the second

and third applications will help prepare budget requests and justifications for anticipated programs.

Fourth and fifth applications involve research planning and training. The model requires specific data about all the Bureau's resource programs, and it integrates these data for decision making. The data are incomplete and, in cases, very uncertain. Future research could easily be aimed at these problems, and the results of such research would be immediately useful for management planning, because they could be included in the model. The model could also be programmed as a management game to give Bureau foresters experience with many resources simultaneously. All the applications mentioned above could easily be used in a training program, and the participants would learn to view each activity as part of, and interrelated with, a larger whole.



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